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DEVELOPMENT OF COLOR SIGNS AND PROJECTIONS OF THE HUNGARIAN ARCHIVE GEOLOGICAL MAPS

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This paper summarizes the early geological maps about Hungary with special respect to their color codes, surface symbol systems and map projections. The process from the *ad hoc* color usage of the earliest maps, through the influence of the color system proposed by the Bologna Geological Congress of 1881 to the symbol system of the modern maps is shown. Analysing the coordinate grids of these map products, the older ones can be rectified in equidistant conic or Cassini projections while the ones of Böckh and Koch and Lóczy et al. can be interpreted as both conic and Budapest-centered Stereographic projected. The ambiguity is because of the relatively low scale of the maps, enabling projection errors of several hundred meters without practical consequences.

Keywords: color systems; geological maps; historical maps; Hungary; map projections

Introduction

According to the traditional classification of the maps, geological maps are thematic ones. Thus, the positions and characteristics of the geological structures and features are indicated by colors, lines and surface signs. The simplification of the geological reality is a function of the applied scale of the map. It was a long process that resulted in the colors that are applied in the modern geological maps.

In the beginning, *ad hoc* colors were used depending on the author of the map. The lithological system of the Earths crust and its application in geological mapping were introduced by Abraham Werner Gottelob and William Smith at the end of the 18th century. The unified color system applied in the modern geological maps is a result of the 1st and the 2nd Geological Congresses held in Paris and Bologna, respectively, at the end of the 19th century. According to this system, the older the geological formation is the darker is its hue in the map (Capellini 1882).

In Hungary, the transition to this new system was a result of a long process (Staub and Szontagh 1886). Early geological maps, e.g. the ones of Townson (1797) and Beudant (1822) used ad hoc colors for different lithological units. The first geological maps that really applied the new color codes, was the Geological Map of Hungary (1893), the summarizing product of the Hungarian Geological Society. It was hand-painted on a printed topographic base map. Its final version was printed three years later, to the Millennial Celebration of Hungary in 1896 (Böckh and Koch 1896). This map was presented at the 1900 World Expo in Paris, where it was awarded by a gold medal (Pálfy 1901, Böckh 1903). It was followed by the 1:900 000 scale geological map of Lóczy et al. (1922). After the WWII, the legends and the symbols of the Hungarian geological maps became gradually unified. This resulted in the systems of colors and surface signs used at the modern products.

The development of the map projections used for these maps was even complex. The early geological maps have equidistant conic (Ptolemaic) projection, with different projection centers. Their latitude-longitude grids used rather the Ferro, sometimes the London prime meridian. However, the progress of map projections gradually appeared in the geological maps too. As the military topography of the Habsburg Empire started the survey of the empire in Cassini-Soldner projection (Hofstätter 1989, Kretschmer et al. 2004, Timár et al. 2006a), the resulted map sheets were used as base maps of geological maps too. Later again, the currently used topographic maps with their pre-defined projections were used as base maps, so the projection of the geological maps were more or less identical to the one of the topographic ones. Even the modern, digital map series of the Hungarian Geological Institute is based on the different projections and sheeting systems that are or were recently used in Hungary.

Details of the color systems used in geological maps

Using only the three base colors and a color combination method, all natural colors can be represented. There are two color combination methods. In the case of the additive combination, the base colors are the red, the green and the blue — this system is used e.g. in the digital photography and the television technology. The base colors subtractive combination are the cyan, the yellow and the magenta (the complementary colors of the additive method), and this is the base of the analogue color photography and the printing and modern press systems.

The human eye is able to detect only a limited number of color hues. As a lot of formations are connected to a geological age even on a small part of the terrain, they cannot be indicated by different colors; the usage of too many hues would result a less readable map. That is why the 2nd Geological Congress in Bologna, 1881, standardized the applicable set of colors and hues on geological maps (Capellini 1882, Staub and Szontagh 1886). These colors are related to geological ages. Therefore, the formations belonging to the same age should be distinguished by surface signatures and some text elements called geological indices

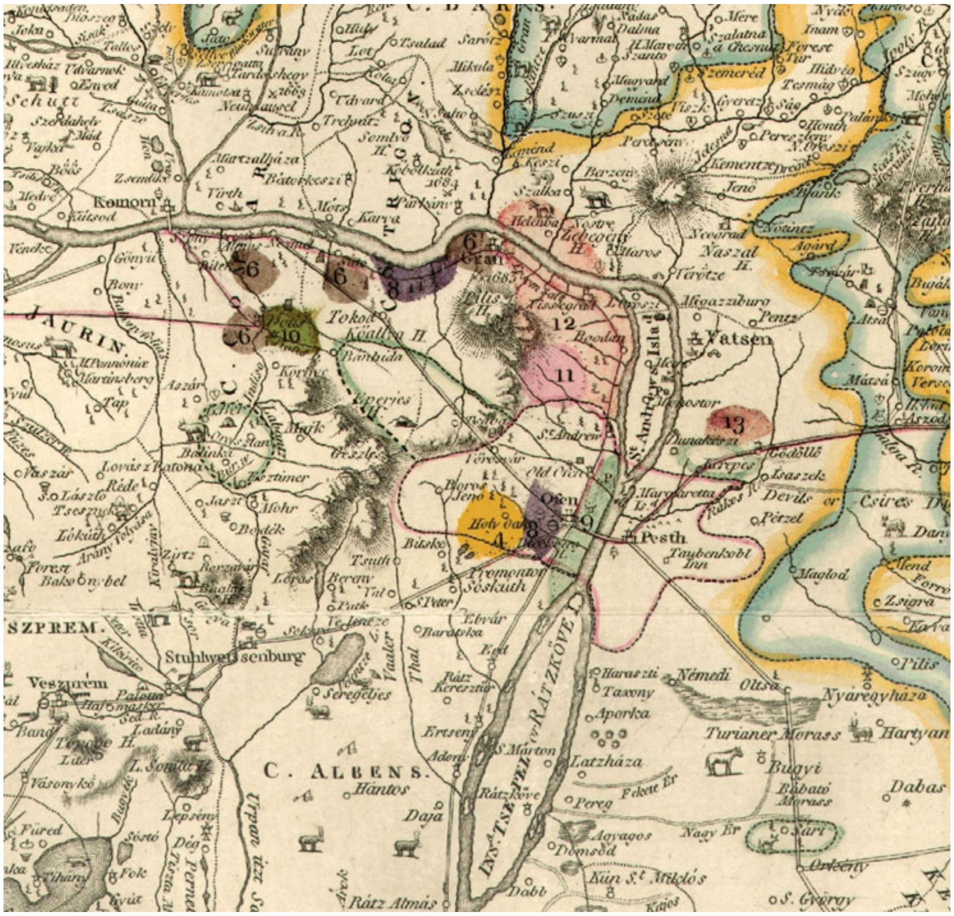

Fig. 1. Part of the map of Townson (1797). Only a small area of the map is indicated as having known geological features along the travel route of the mapmaker

(Galambos 2004). This chapter shows the process of the introduction of this system — a process that leads from the early maps with only a few mapped features to the modern ones with thousands of lithological units and features.

The first geological map of Hungary was published as an addendum to a travel report to Hungary of Townson (1797). It was drawn on the topographic map of Korabinszky, indicating 13 different rock types along his travel route only (Fig. 1). The stations of his travel were also shown. He gave the references of his pieces of information: "When Colours in Stripes run diagonally, there the Rocks are composed of the different kinds of Rocks signified by those Colours. The Colours which form only an Outline, do not refere to the Petrography, but to the People".

The first geological map of Hungary showing systematically the territory of the whole country was completed by Beudant (1822) at a scale of 1:1 million and was based on his travels in 1818 (Fig. 2). Here the different geological units are indicated

Fig. 2. The first systematic geological map showing the full territory of the historical Hungary by Beaudant (1822). The color system is still *ad hoc*, and there is no similarity to the modern color codes of the geological maps

by number codes, numbering from the oldest to the youngest formations. There are similarities between the maps of Townson (1797) and Beudant (1822) but as their methodology is completely different, they are hardly compatible ones.

Similarly to the above-mentioned 1893–1896 map of the Society, the geological map of Lóczy et al. (1922) compiled between 1890 and 1910 follows the color coding system introduced by the Bologna Congress (Fig. 3). The map of Lóczy et al. (1922) was printed using 35 different direct colors, which is the highest figure in the Hungarian map printing (Fodor 1954, Fig. 4). The 1:300 000 scale geological map of Balogh (1956) has a unified lithologic and stratigraphic surface symbol system, showing 30 Quaternary and 67 older formations; Fig. 5, left. On the contrary, the map of Fülöp (1967, Fig. 5, right) shows back to the earlier mapping methods by using the number codes along with the standard age classification (Fülöp et al. 1975). It shows 26 Quaternary and 101 older formations (Gyalog 1996, Fig. 5).

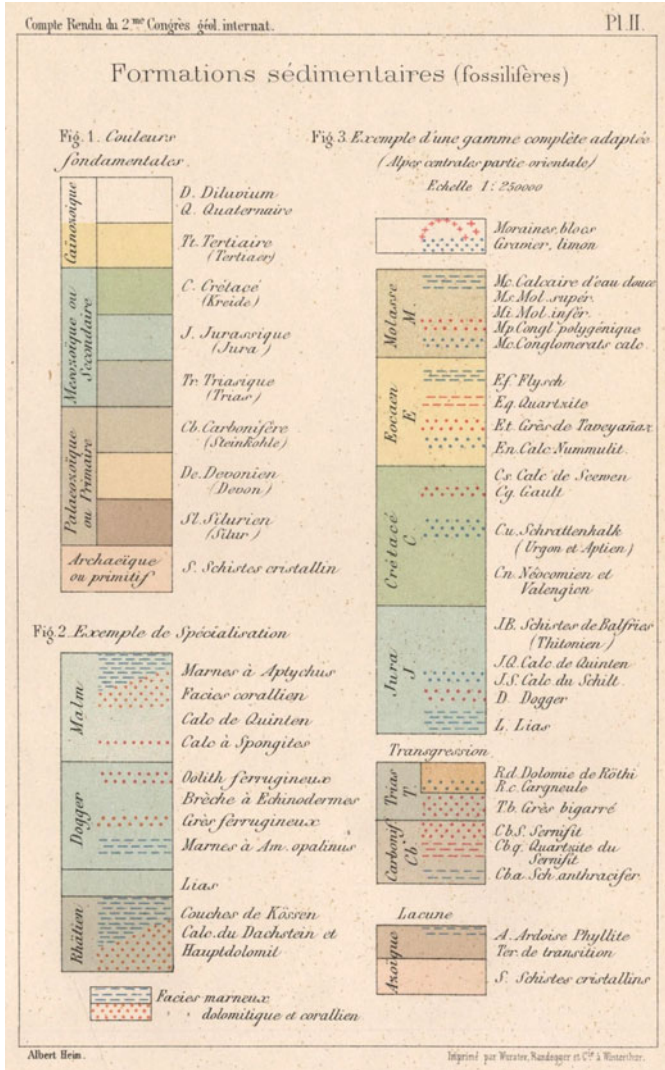

Fig. 3. Part of the protocol of the 2nd Geological Congress, Bologna, 1881 (Capellini, 1882)

Map projections of the early Hungarian geological maps

The maps compiled prior to the Second Military Survey (generally prior to 1820) have equidistant conic projection. This projection was used in the maps of Townson (1797) and Beudant (1822). This latter one has an interesting characteristic: its prime meridian is London, which is generally unusual of the time of that map.

The sheet of the geological atlas showing Lake Balaton was constructed using the base maps of the Second Military Survey; therefore, it has Cassini (or Cassini-Soldner) projection with the projection center at the Stephansdom in Vienna.

Fig. 4. The map of Lóczy et al. (1922) of the whole Pannonian Basin and its surroundings printed in 35 unique colors

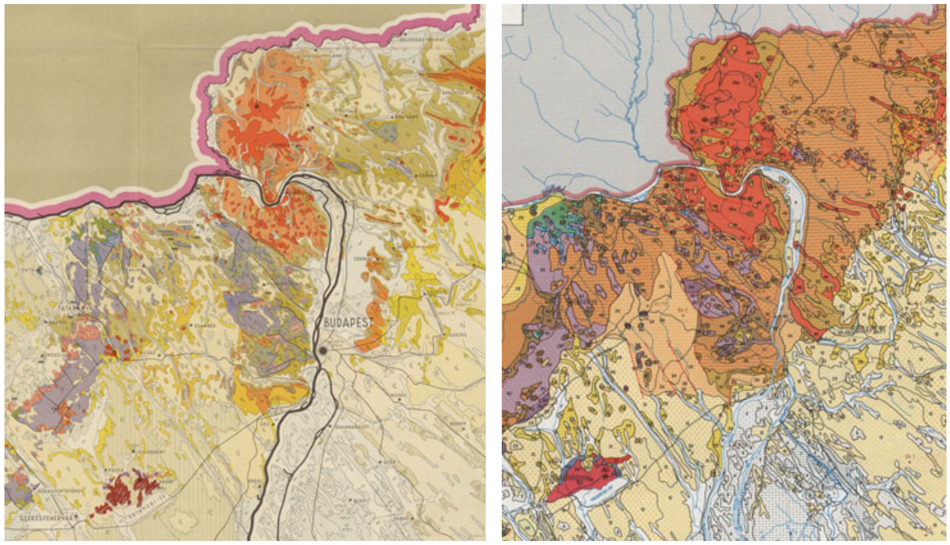

Fig. 5. Part of the maps of Balogh (1956, left) and Fülöp (1967, right). Albeit of the different surface symbols and numbering systems, they both are conform to the Bologna color code system of the geological ages

The map of Böckh has true conic projections with Ferro prime meridian (20 degrees in round numbers west of Paris). The colorful map of Lóczy et al. used the base map with a standard projection of topographic maps of that time, the Budapest-centered Stereographic one, with the Greenwich prime meridian. From the 1950s, the conic projected base map of the Soviet bloc was used (e.g. on the Mahel' map). The modern 1:100 000 scale series of the Hungarian Geological Institute has a Hungarian EOV coordinate grid (oblique conformal cylindrical projection) but its sheet system is based on the Gauss-Krüger maps of the former Warsaw Pact.

The above list describes only the projection types of the different maps. To fit the map content to the modern coordinate systems, the detailed parameters of the projections should be given. In the case of the equidistant conic and the Cassini-Soldner projections, the parameters are the latitude and longitude of the projection center on the ellipsoid, and the easting and northing values of the same center on the projected plane (Snyder 1987).

As in the early geological maps there are no projection grid coordinates indicated, the analysis is based on what there are: the arcs of meridians and parallels. As the parallels are concentric circles and the meridians are lines converging to the same point, crossing all parallels at right angle, these maps have real conic projection. This projection type, especially the equidistant conic projection was characteristic of the 18th century cartography. The problem is that in the Beudant map not even the parallels and meridians are drawn. They are found in the Townson map but its prime meridian of 'London' is not recognized. It is definitely not the same to the modern 'Greenwich' meridian as the observatory of Greenwich was built later by Airy. There is a consistent east-west shift of cca. 20 kilometers

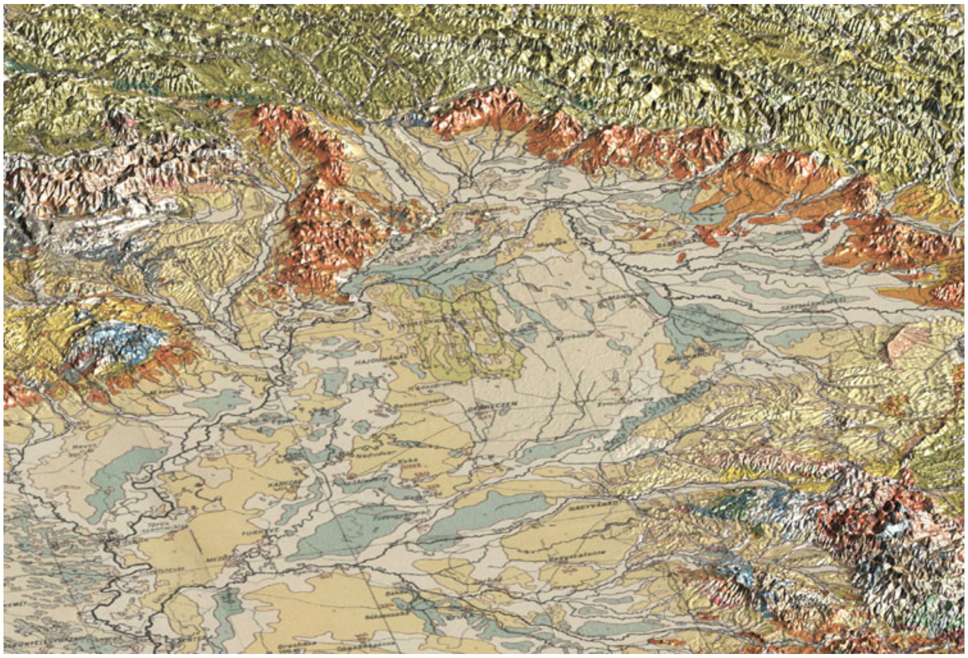

Fig. 6. Combination of a modern digital elevation model (SRTM; Farr et al. 2007) and the map of Lóczy et al. (1922), a possible utilization of georeferencing an archival geological map

between the two prime meridians. Therefore, both maps were rectified using ground control points (GCPs) with known geographic coordinates. Using these GCPs, the type of the projection was guessed — the less the maximum error at the GCPs, the more probable the projection type. The latitude of the center of a real conic projection was estimated using the method of Timár et al. (2003a). The longitude of the projection center is taken at the geometric center of the map. Fortunately, in the case of such low-scale maps, the parameters of the base ellipsoid and the geodetic datum are not a real issue. Their effect causes an error less than half a kilometer, which is not detectable at a scale around 1:1 million.

Using the method, the most probable projection type of the Townson map is the Cassini-Soldner. However, even in this projection, the mapped drainage system is somewhat distorted and errors up to 10 kilometers occur at some identified settlements. The map of Beudant has a real conic projection with a projection center at $\Phi = 40°$; $\Lambda = 20°$ from Greenwich. Interestingly enough, the latitude of the center is the same as that of the topographic map of Lipszky surveyed between 1804 and 1810 (Bartha 1992, Reisz 2002, Timár et al. 2006b), which was the most up-to-date cartographic product showing Hungary in the time of the Beudant geological survey.

Like in geology, the end of the 19th century brought a real change of paradigm also in geodesy. In 1884, the Washington Congress on the fixing of the prime meridian and the universal day (ICW 1884) the Greenwich meridian was selected as an international standard for all later maps. In Hungary, the Ferro prime meridian was used before that, and the compulsory change to Greenwich was effective only in 1914. The change is obvious in the maps of Böckh and Lóczy et al.: the first one had the prime meridian of Ferro, while the latter one Greenwich. The coordinate line analysis provides either the equidistant conic or the Budapest-centered Stereographic (Mugnier 1999, Timár et al. 2003b) projections for both maps. The difference between the errors at GCPs at the two projections are less than the detectable distance in these maps at a scale around 1:1 million.

Summary

The unified color code system, introduced by the 2nd Geological Congress of Bologna, 1881, was effective in the Hungarian geological maps from the end of the 19th century. Prior to this date, the colors of the early geological maps were rather random ones. According to the Bologna system, the different ages of the geological features are indicated by distinct colors. The usage of the Greenwich prime meridian in the Hungarian geological maps became characteristic after the WWI.

The map projections used for the different maps are connected to the ones used in the mainstream topographic maps of the time of the map making. The map of Townson (1797) can hardly be interpreted as a projected one, but the most probable projection is the one of Cassini. After the topographic map of Lipszky (1804–1810), the map of Beudant has not only the same projection type (equidistant conic), but exactly the same parameters of the projection. The geological maps of the late 19th and early 20th century can be properly georeferenced using the Budapest-centered Stereographic projection.

Georeferencing these maps enables us to incorporate their knowledge base in the modern GIS databases and also to construct electronic maps with combined historical and modern databases (Fig. 6).

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